

Soft Computing Adaptations in System Analysis and Design

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The field of system analysis and design has attracted considerable recent attention, largely motivated by recognition that the design and development of complex systems can no longer be conducted by handling their different components in isolation. Both an increased level of complexity within the system components, and the desire to extract the advantages of a synergistic design process, dictate the need for a more comprehensive approach. Computational resources available to a design engineer have continued to increase exponentially. Even in the face of these improvements, however, the increased level of complexity in design requirements has continued to pose significant challenges to the design engineer. Practical-scale system design problems are characterized by large number of design variables and constraints, analysis from contributing components that are not completely independent and indeed demonstrate one- or two-way couplings, and numerically expensive mathematical models of component and system behavior. Perhaps the most confounding complexity stems from a lack of knowledge, or uncertainty, about the characteristics of the systems under consideration. It is against this backdrop of analysis and design needs that soft computing methods have assumed an important role in contemporary design practice.

The focus on soft computing methods has derived from the need for computational tools that more closely model the working of the human mind, certainly for its ability to show greater tolerance for imprecision, uncertainty, and approximations in obtaining high-quality engineering solutions. The present paper provides an overview of the adaptation of such techniques in problems of structural and multidisciplinary design of aerospace systems. The use of neural networks and fuzzy-logic based tools for modeling system analysis, representing imprecise information in a formal design process, and discovery of causal relationships in design data is presented in the context of coupled system analysis and design. The adaptation of genetic algorithms and immune network modeling, especially in generically difficult design optimization problems, has been shown to be particularly effective. The extension of these computing paradigms in machine learning and classifier systems, and their application to engineering design, is also explored.

The paper also examines the role of soft computing methods in analysis and design algorithms developed for distributed computing environments. A specific example of this algorithm is the decentralized computing approach referred to as the cellular automata. The adaptation of this computing model in problems of structural analysis and optimization is presented, including its extension in problems containing parametric uncertainties. The application of soft computing tools to discover fundamental rules for cellular automata evolution, as well as the use of the automata model to study the propagation of uncertainties in system design is also explored.